

IN THE SPECIFICATION:

Please replace the THIRD full paragraph of specification page 1 with the following replacement paragraph:

In logic and computer ~~systems~~systems, transmission line drivers typically began by transmitting unipolar logic (voltage) signals over matched transmission lines. Types of transmission lines used in such systems include, but are not limited to, single and paired wires, twisted pairs, shielded twisted pairs, flat cables, flat cables with a ground shield, and coaxial. The terminating resistor, equal to the line's characteristic impedance, is connected across the distant end of the transmission ~~line~~line between the signal and the return lines. The matching substantially eliminates reflections or ringing when the loading of the receiving circuitry impedance is one or more orders of magnitude higher than the characteristic impedance at the signal frequencies.

Please replace the FOURTH full paragraph of specification page 1 with the following replacement paragraph:

FIG. 1 shows a prior art logic voltage signal 10 driving a transmission line 12. When terminated with the lines characteristic impedance R_t , ~~substantially the voltages~~voltage signal 10 is reproduced 12 across R_t . The return current will contribute to a noise signal V_n as will electrostatically and electromagnetically coupled signals from fast changing voltage and current signals in nearby circuits. Power dissipation, for example

+3.3 V across a 50 ohm termination, speeds and noise V_n continue to limit the uses of driving voltage signals.

Please replace the SECOND full paragraph of specification page 2 with the following replacement paragraph:

One improvement was to reduce the voltage signal levels, and to use differential voltage drivers and receivers, but. ~~But~~, the same issues ~~remain~~ remain, albeit at a lower level.

Please replace the FORTH full paragraph of specification page 2 with the following replacement paragraph:

It has been recognized that current driving techniques may have a number of advantages with respect to speed, power dissipation, noise, and jitter. FIG. 2 illustrates one advantage comparing a low voltage differential signal (LVDS) Vs driver and a current transfer logic (CTL) Is driver. The analysis assumes that the receiving end of the transmission line senses voltage for the LVDS and current for the CTL circuit. In one case, an LVDS driver results in 3.5 ma of current into the line, or a voltage at the driver of 350mV. These levels are needed because there will be voltage loss along the line and the receiver may receive only 100mV. The lost 250 mV represents a noise margin at the driver and attenuation due to the transmission line. Any other any noise contributions will further reduce that margin. For the CTL, a current, I_s , is sent, and, assuming good quality transmission lines, and using Kirchoff's current (or charge) law, that DC current will be received at the receiver. So, a reduced current can be used with CTL resulting in

substantially lower noise and power dissipation. Further, an effect of the reduced current, from FIG. 2, is that the dv/dt for the CTL is shorter than the dv/dt edge for V_s (with the same slopes) resulting in higher speed for the CTL circuit, since the signals reach their half way point faster. Moreover, for the same speed, the di/dt for the CTL circuit may be made substantially slower 20 resulting in ~~additionally-lower noise~~ EMI and lower jitter signals.

Please replace the FIRST full paragraph of specification page 3 with the following replacement paragraph:

Other problems limit the LVDS system. For example, at the receiver, the LVDS will drive a current I through the terminating resistor. Prior art designs sense that voltage with a high gain amplifier, but. ~~But~~ the slew rate of the voltage signal is limited by the I/C , where C may be considerable since it is the capacitance related to the high gain amplifier required by the LVDS approach. Lowering the voltage across the terminating resistor does not help since the noise margin at the receiver will be reduced and a higher gain amplifier will effectively increase capacitance and reduce bandwidths (gain bandwidth tradeoff).

Please replace the SECOND full paragraph of specification page 3 with the following replacement paragraph:

Current drivers for transmission lines are known, but such systems often use a voltage sensing across the termination resistor, and as ~~such~~ such, suffer from many of the same problems associated with high gain voltage receiving ~~amplifiers~~ amplifiers.

Please replace the FOURTH full paragraph of specification page 3 with the following replacement paragraph:

U.S. patent no. 6,476,642 B1 to Morano (Morano), filed July 2000, applies a differential current driver to drive signal buses like those found on electronic backplanes. FIG. 3 diagrams such a circuit. Here the transmission line comprises two signal lines where Morano pushes a positive current I_1 into one line and pulls an equal negative current I_1 from the second line. Care is taken using a complex feedback bridge type circuit to balance those currents to ensure proper operation. If ~~imbalancees~~imbalances occur, the voltage across the R_t may be offset which may negatively affect the sensing circuit operation.

Please replace the FIRST full paragraph of specification page 4 with the following replacement paragraph:

In view of the foregoing background discussion, the present invention provides a current mode transfer logic transmission line driver system and method. The inventive system provides two transmission lines each driven from unbalanced or unequal current sources. The unequal current sources are switched between the two transmission lines in response to a logic signal. The distal ends of the transmission lines share a termination resistor arranged between their signal carrying conductors. The unequal currents are sensed at the distal end, and when the unequal currents are switched between the transmission ~~lines~~lines, a different logic state is detected. The current mode driving and cur-

rent sensing at the distal ends of the transmission lines, compared to voltage sensing, provide, at least, speed, power, noise and jitter advantages.

Please replace the SECOND full paragraph of specification page 4 with the following replacement paragraph:

In preferred ~~embodiments~~embodiments, the current sensing is accomplished using diode connected MOS transistors biased at an impedance level that does not substantially affect the transmission line termination. Part of the current in each transmission line is shunted from the terminating resistor through the diode connected transistors.

When the input signal logic state ~~changes~~changes, the currents shunted will change ~~accordingly~~accordingly, thereby indicating the new logic state.

Please replace the THIRD full paragraph of specification page 4 with the following replacement paragraph:

After the current sensing at the distal ends of the transmission lines, in a preferred embodiment, the currents are independently amplified and converted into a voltage signal related to the difference between the unequal currents. The conversion to a voltage signal affords system ~~compatibility~~compatibility with typical logic systems. However, the conversion to a voltage signal occurs where capacitance effects substantially do not affect the speeds, noise margins, or jitter of the received logic signal. In another embodiment, a differential current may be sensed, amplified and then converted into a voltage signal.

Please replace the FOURTH full paragraph of specification page 4 with the following replacement paragraph:

In ~~practice-practice~~, the unequal currents into the jointly terminated transmission lines will return a current equal to the difference between the two currents through the shields or return current paths of the two transmission lines. In one ~~embodiment-em-~~
bodiment, a single twisted pair cable is used for signal transmission. In this case there are only the two in the cable and no shield. ~~First~~ The first wire carries forward current equaling I while the return current $I/2$ returns in the second wire.

Please replace the FIRST full paragraph of specification page 5 with the following replacement paragraph:

The invention description below refers to the accompanying drawings, of which:
FIGS. 1 and 3 are circuit diagrams of prior art line driver ~~circuits~~, circuits;
FIG. 2 is a signal comparison of an LVDS to a CTL circuit;
FIG. 4A and 4B are a block diagrams of ~~a preferred~~ preferred embodiments of the present invention;
FIG. 5 is a schematic of a differential current line ~~driver~~, driver;
FIG. 6 is a circuit illustrating current ~~sensing~~, sensing; and
FIG. 7 is combined schematic of a receiver circuit.

Please replace the SECOND full paragraph of specification page 5 with the following replacement paragraph:

FIG. 4A ~~show~~ shows a diagram of a preferred embodiment of the present invention. An input signal, V_{in} controls and selects output current signals I_a and I_b that are driven into the transmission lines 50 and 52. In one logic ~~state-state~~, I_a is a positive current out into a first transmission line 50 and I_b is a negative current in from a second transmission line 52. In the opposite logic ~~state-state~~, I_a is a negative current from the

first transmission line 50 and Ib is a positive current into the second transmission line 52.

In another preferred ~~embodiment~~ embodiment, it is possible to have no current driven into either transmission line.

Please replace the FIRST full paragraph of specification page 6 with the following replacement paragraph:

If each transmission line has a characteristic impedance of 50 ~~ohms~~ ohms, a 100 ohm R_t is placed across the distal ends of the signal conductors and serves to terminate both lines. Of note is that Ia and Ib are not equal to each other so that there will be a return current through the shield. Also, since R_t is across the distal ends of both transmission lines, both ends of R_t will be biased at some positive voltage in this preferred embodiment. Preferably, in one logic state, Ia is +1 ma and Ib is -0.5 ma, whereupon there is a return current, Is, in the shield of 0.5 ma. In the opposite logic state there still will be 0.5 ma returned through the shield.

Please replace the FOURTH full paragraph of specification page 6 with the following replacement paragraph:

FIG. 5 shows one current driver circuit that may be used in accordance with the present invention. Here, when V1 is low P1 is on and I1, 1mA, travels via P1 out as Ia. If V2 is high N2 is on and I2, 0.5mA, travels out via N2 as a negative Ib. Reversing the logic states of V1 and V2, I2 travels out as a negative Ia and I1 travels out as a positive Ib. Typically, V2 is designed as the logic inverse of V1 for the above operation. However, if P1, P2, N1 and N2 are driven independently (not shown), it will be possible to

turn them all off leaving no current in the transmission lines. ~~Reader should note~~ It should be noted that ~~the~~ no common mode feedback ~~circuit~~ circuit (CMFB) is used to stabilize the common mode level of the output voltage. This circuit is typical for an LVDS style driver. CTL ~~doesn't~~ does not require CMFB due to the special receiver used at the other end. ~~Thus we save~~ end, thus saving the current consumed by the CMFB circuit reducing the total power consumption of the system.

Please replace the FIRST full paragraph of specification page 7 with the following replacement paragraph:

FIG. 6 is a schematic of a current sensing circuitry consistent with a preferred embodiment of the present invention. ~~Here~~ Here, two diode connected NMOS transistors, N3 and N4, are biased to siphon off I3 and I4, respectively, from currents in the transmission lines. N3 and N4 may be biased (not shown) along the diode-like curve to overcome any threshold and to present an impedance substantially greater than R_t to minimally affect the termination of the transmission lines. In one preferred ~~embodiment~~ embodiment, N3 and N4 exhibit about 1 K ohms each, although other impedances can be used as known in the art. If N3 and N4 present about 2 K ohms across an equivalent 100 ohm transmission line, the R_t can be made equal to 105 ohms or appropriately higher or lower to maintain proper transmission line termination. However, as is known in the art, there is likely to be some harmless ringing due to some impedance mismatch even if care is taken to keep the diode transistors at a high impedance state. For ~~example~~ example, if R_t is 105 ohms across a 100 ohm transmission line, and the diode connected transistors

present, for some processing reason, ~~a~~very very high impedances, the 5 ohm mismatch will only result in a reflection coefficient of about less than 2.5 percent.

Please replace the SECOND full paragraph of specification page 7 with the following replacement paragraph:

Still referring to FIG. 6, consider that I_a is 1 ma, I_b is -0.5 ma, then the return current, I_s , will be 0.5 ma. N3 and N4 can be designed so that I_t is 0.65 ma, with N3 drawing I_3 of 0.35 ma and N4 drawing I_4 of 0.15 ma. The difference between I_3 and I_4 , or 0.2 ma, is sensed, as discussed below, to indicate a logic signal, say a logic one. The negative of that logic signal is sensed when I_a and I_b exchange current levels when the input signal to the current drive changes state. In this ~~state-state~~, I_3 and I_4 will exchange current levels and 0.2 ma difference is sensed as a logic zero. So a logic change from one to zero will result in 0.4 ma change in current.

Please replace the FIRST full paragraph of specification page 8 with the following replacement paragraph:

In FIG. 7 the current sense circuit 54 is formed by a circuit attached to each end of R_t , with a current source I_5 and I_6 feeding each circuit. As known in the art, these current sources will be typically formed by biasing PMOS transistors to the positive power rail 60. The current sensing circuit for I_3 includes N5 - N8. N7 and N8, and the current sensing circuit for I_4 includes N5' - N8'. N7 and N7' are diode connected NMOS transistors that share equal drain currents with N8 and N8', respectively. Since N7 and N8 have the same drain current (~~I_5~~)(I_5), the gate to source voltage for N7 and N8 are equal,

assuming matched transistors. The discussion for N5 – N7 with respect to I3 applies directly to N5' – N7' with respect to I4, and so is not repeated below. N6 is the diode connected transistor arranged with N5 forming a controlled transistorized linear resistance to bias the diode connected devices away from the knee region and thus increase the current sensitivity. Resistances of N5 and N5' are controlled by the gate voltage of N7 and N7', respectively, which in turn depends on current in the diode connected devices N6 and N6'. Thus the current information from the sensing element (diode connected device) is used to modify the resistance of N5 or N5' such that the effective current difference between the two branches can be increased. Resistance also has a dampening effect on a high frequency noise which appears on node A and Ab. In this circuit arrangement I5, N7 and N8 control, via the mirroring effect, I3 and the voltage drops across N5 and N6, as follows. The same current will travel through N5 and N6 so that their gate to source voltages will be equal to each, and the voltage at Pin+ via the N7 mirror. In this manner manner, the offset voltage of the diode connected N6 can be compensated and the impedance of N6 can be controlled.

Please replace the SECOND full paragraph of specification page 8 with the following replacement paragraph:

The gates of N9 and N10 connect to the drain of N6, marked A, forming a current mirror. Similarly, N11 and N12 mirror the current in N6.' N10 and N12 are sized to provide amplified currents sensed by the I-V conversion circuit via B and Bb. When I3 changes, in a preferred ~~embodiment~~ embodiment, from 0.15 ma to 0.35 ma, this change is

reflected at I9 and I10 via the current mirror amplification circuit 56. I10 can be made as an amplified version of the I3 change by sizing the transistors as is known in the art.

Also, P9 is arranged as a diode connected transistor and may be biased (not shown) and I10 will mirror I9 but may be amplified by sizing P10. The gate to source voltage of P10 and P9 are equal. This provides the current amplification so that I10 is an amplified version of I3. ~~As~~ A similar circuit receives I4 and provides an amplified version at I12.